

WHAT IS CLAIMED IS:

1. A substrate bearing a low-emissivity coating, the low-emissivity coating comprising, moving outwardly from the substrate:
 - 5 a) a first film layer comprising silicon dioxide formed directly upon the substrate at a thickness of less than 100 angstroms;
 - b) a second film layer comprising a transparent dielectric material;
 - 10 c) a third film layer comprising an infrared-reflective material; and
 - d) a fourth film layer comprising a transparent dielectric material.
2. The substrate of claim 1 wherein the first film layer comprising silicon dioxide has a thickness of less than about 90 angstroms.
- 15 3. The substrate of claim 2 wherein the first film layer comprising silicon dioxide has a thickness of between about 50 angstroms and about 90 angstroms.
- 20 4. The substrate of claim 3 wherein the first film layer comprising silicon dioxide has a thickness of about 75 angstroms.
5. The substrate of claim 1 wherein the second film layer comprises silicon nitride.
- 25 6. The substrate of claim 5 wherein the second film layer comprising silicon nitride is formed directly upon the first film layer comprising silicon dioxide.
7. The substrate of claim 1 wherein the second film layer comprises zinc oxide.

8. The substrate of claim 7 wherein the third film layer is formed directly upon the second film layer comprising zinc oxide and said infrared-reflective material is silver.

5 9. The substrate of claim 1 further comprising a protective film layer positioned between the third and fourth film layers, the protective film layer being formed directly upon the third film layer.

10. The substrate of claim 9 wherein the protective film layer comprises a material selected from the group consisting of niobium, titanium, nickel, and chromium.

11. The substrate of claim 1 wherein the fourth film layer comprises zinc oxide.

12. The substrate of claim 1 wherein the fourth film layer comprises silicon nitride.

13. The substrate of claim 1 further comprising a titanium nitride film layer further from the substrate than the fourth film layer.

14. The substrate of claim 1 further comprising a chemically durable film layer further from the substrate than the fourth film layer, the chemically durable film layer comprising silicon nitride.

15. The substrate of claim 1 further comprising a titanium nitride film layer and a chemically durable film layer, both being further from the substrate than the fourth film layer, wherein the chemically durable film layer comprises silicon nitride.

25 16. The substrate of claim 1 further comprising:

30 a) a fifth film layer comprising an infrared-reflective material; and
b) a sixth film layer comprising a transparent dielectric material.

17. The substrate of claim 16 wherein said infrared-reflective material is silver.

18. The substrate of claim 17 wherein the fifth film layer is formed directly upon the fourth film layer and the fourth film layer comprises zinc oxide.

19. The substrate of claim 16 further comprising a protective film layer positioned between the fifth and sixth film layers, the protective film layer being formed directly upon the fifth film layer.

20. The substrate of claim 19 wherein the protective film layer comprises a material selected from the group consisting of niobium, titanium, nickel, and chromium.

21. A substrate bearing a silver-based low-emissivity coating, the low-emissivity coating including a first film layer comprising silicon dioxide formed directly upon the substrate at a thickness of less than 100 angstroms, the coating further including at least one infrared-reflective silver-containing film layer.

22. The substrate of claim 21 wherein the silver-based low-emissivity coating includes at least two infrared-reflective silver-containing film layers.

23. A transparent substrate having a given index of refraction, the substrate bearing a low-emissivity coating comprising, moving outwardly from the substrate:

- a first film layer comprising transparent material having an index of refraction substantially equal to that of the substrate, the first film layer being formed directly upon the substrate at a thickness of less than 100 angstroms;
- a second film layer comprising a transparent dielectric material;
- a third film layer comprising an infrared-reflective material; and
- a fourth film layer comprising a transparent dielectric material.

24. The substrate of claim 23 wherein the index of refraction of the substrate is between about 1.4 and about 1.5.

25. The substrate of claim 24 wherein the index of refraction of the transparent material of the first film layer is between about 1.4 and about 1.5.

5 26. The substrate of claim 23 wherein the first film layer has a thickness of less than about 90 angstroms.

10 27. The substrate of claim 23 wherein the transparent material of the first film layer is silicon dioxide.

15 28. The substrate of claim 27 wherein the substrate is a sheet of soda lime glass.

20 29. A transparent substrate having a given index of refraction, the substrate having a moisture-corroded major surface bearing a low-emissivity coating comprising, moving outwardly from the substrate:

25 a) a first film layer of amorphous material formed directly upon said moisture-corroded major surface of the substrate, the first film layer having a thickness of less than 100 angstroms;

30 b) a second film layer comprising a transparent dielectric material;

35 c) a third film layer comprising an infrared-reflective material; and

40 d) a fourth film layer comprising a transparent dielectric material.

45 30. A substrate bearing a low-emissivity coating, the low-emissivity coating comprising, moving outwardly from the substrate:

50 a) a first film layer comprising silicon dioxide formed directly on the substrate;

55 b) a second film layer comprising a transparent dielectric material;

60 c) a third film layer comprising an infrared-reflective material;

65 d) an intermediate film region comprising at least three film layers;

70 f) a seventh film layer comprising an infrared-reflective material; and

75 g) an eighth film layer comprising a transparent dielectric material.

31. The substrate of claim 30 further comprising a protective film layer positioned between the third film layer and the intermediate film region, the protective film layer being formed directly upon the third film layer.

5 32. The substrate of claim 31 wherein the protective film layer comprises a material selected from the group comprising niobium, titanium, nickel, and chromium.

10 33. The substrate of claim 30 wherein the intermediate film region includes at least one substantially amorphous film layer.

15 34. The substrate of claim 33 wherein said substantially amorphous film layer is silicon nitride.

20 35. The substrate of claim 30 wherein each of said three film layers in the intermediate film region has a physical thickness of no more than about 250Å.

25 36. The substrate of claim 30 wherein each of said three film layers in the intermediate film region is formed of a different material than each film layer contiguous thereto.

30 37. The substrate of claim 30 wherein said three film layers in the intermediate film region are formed respectively of a zinc oxide, a silicon nitride, and a zinc oxide.

38. The substrate of claim 37 wherein said silicon nitride film layer is positioned between said zinc oxide film layers.

25 39. The substrate of claim 30 wherein the intermediate film region comprises at least five film layers.

30 40. The substrate of claim 39 wherein the intermediate film region comprises alternating film layers of zinc oxide and silicon nitride.

41. The substrate of claim 40 wherein the intermediate film region comprises three zinc oxide film layers and two silicon nitride film layers.

42. The substrate of claim 30 wherein the first film layer comprising silicon dioxide has a thickness of less than 100 angstroms.

5 43. The substrate of claim 42 wherein the first film layer comprising silicon dioxide has a thickness of between about 50 angstroms and about 90 angstroms.

44. A substrate bearing a low-emissivity coating, the low-emissivity coating comprising, moving outwardly from the substrate:

10 a) a first film layer comprising silicon dioxide formed directly upon the substrate;

b) a second film layer comprising a transparent dielectric material;

c) a third film layer comprising an infrared-reflective material;

d) a fourth, protective film layer formed directly upon the third film layer, the fourth, protective film layer being a niobium-containing film layer; and

e) a fifth film layer comprising a transparent dielectric material.

45. The substrate of claim 44 further comprising:

25 a) a sixth film layer comprising an infrared-reflective material;

b) a seventh, protective film layer formed directly upon the sixth film layer, the seventh, protective film layer being a niobium-containing film layer; and

c) an eight film layer comprising a transparent dielectric material.

30 46. A substrate bearing a low-emissivity coating, the low-emissivity coating comprising, moving outwardly from the substrate:

35 a) a first film layer comprising silicon dioxide formed directly upon the substrate at a thickness of less than 100 angstroms;

b) a second film layer comprising an oxide of zinc and tin;

c) a third film layer comprising an oxide of zinc;

- d) a fourth film layer comprising an infrared-reflective material;
- e) a protective fifth film layer formed directly upon the fourth film layer;
- 5 f) a sixth film layer comprising an oxide of zinc;
- g) a seventh film layer comprising an oxide of zinc and tin;
- 10 h) an eighth film layer comprising an oxide of zinc;
- i) a ninth film layer comprising an infrared-reflective material;
- j) a protective tenth film layer formed directly upon the ninth film layer;
- 15 k) an eleventh film layer comprising an oxide of zinc;
- l) a twelfth film layer comprising an oxide of zinc and tin; and
- m) a thirteenth film layer comprising silicon nitride.

20 47. A substrate bearing a low-emissivity coating, the low-emissivity coating comprising, moving outwardly from the substrate:

- a) a first film layer comprising silicon dioxide formed directly upon the substrate at a thickness of less than 100 angstroms;
- b) a second film layer comprising titanium oxide or silicon nitride;
- c) a third film layer comprising an oxide of zinc;
- 30 d) a fourth film layer comprising an infrared-reflective material;
- e) a protective fifth film layer formed directly upon the fourth film layer;
- f) a sixth film layer comprising silicon nitride;
- 35 g) a seventh film layer comprising an oxide of zinc;
- h) an eighth film layer comprising an infrared-reflective material;
- 40 i) a protective ninth film layer formed directly upon the eighth film layer; and
- k) a tenth film layer comprising silicon nitride.